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FOR

USE OF IRIDIUM COUPLING LAYER IN AP-TAB MAGNETIC HEAD

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USE OF IRIDIUM COUPLING LAYER IN AP-TAB MAGNETIC HEAD

FIELD OF THE INVENTION

The present invention relates to magnetic heads, and more particularly, this invention relates to read heads having magnetically pinned tab regions.

BACKGROUND OF THE INVENTION

One well known way to increase the performance of hard disk drives is to increase the areal data storage density of the magnetic hard disk. This can be accomplished by reducing the written data track width, such that more tracks per inch can be written on the disk. To read data from a disk with a reduced track width, it is also necessary to develop sufficiently narrow read head components, such that unwanted magnetic field interference from adjacent data tracks is substantially eliminated.

The standard prior art read head elements include a plurality of thin film layers that are deposited and fabricated to produce a GMR read head, as is known to those skilled in the art. Significantly, where the width of the thin film layers that comprise the GMR read head is reduced below certain values, the magnetic properties of the layers are substantially compromised. To overcome this problem, GMR read heads have been

developed in which the thin film layers have an ample width, and bias layers and electrical leads are overlaid on top of outer "tab" regions of the thin film layers. This lead overlaid configuration has the effect of creating an active read head region having a width that is less than the entire width of the deposited layers, such that the magnetic properties of the thin film layers can be preserved. Thus, in the lead overlaid GMR read heads of the prior art, active magnetic layer portions exist between the electrical leads and passive magnetic layer portions exist beneath the electrical leads.

FIG. **1** is a side cross-sectional view of a prior art electrical lead overlaid read head portion of a magnetic head **100**. As depicted therein, the prior art lead overlaid read head generally includes a substrate base **102** that constitutes the material from which the magnetic head is fabricated, such as aluminum titanium carbide. A first magnetic shield **104** is fabricated on the substrate, and an insulation layer **106**, typically composed of aluminum oxide, is fabricated upon the magnetic shield **104**. A seed layer **108** is deposited upon the insulation layer **106** and a series of thin film layers are sequentially deposited upon the seed layer **108** to form a GMR read head. In this structure, the layers generally include an antiferromagnetic layer **114**, a pinned magnetic layer **118** that is deposited upon the anti ferromagnetic layer **114**, a spacer layer **122** that is deposited upon the pinned magnetic layer **118**, a free magnetic layer **126** that is deposited upon the spacer layer **122** and a cap layer **130** that is deposited upon the free magnetic layer **126**. Typically, the antiferromagnetic layer **114** may be composed of PtMn, NiMn or IrMn, the pinned magnetic layer **118** may be composed of CoFe, the spacer layer **122** may be composed of Cu, the free magnetic layer **126** may be composed of CoFe and the cap layer **130** may be composed of Ta.

Following the deposition of the GMR read head layers **114-130**, a patterned etching process is conducted such that only central regions **140** of the layers **114-130** remain. Thereafter, hard bias elements **148** are deposited on each side of the central regions **140**. Following the deposition of the hard bias elements **148**, electrical lead elements **154** are fabricated on top of the hard bias elements **148**. As depicted in FIG. **2**, inner ends **156** of the leads **154** are overlaid on top of tab regions **160** of the layers **114-130** of the central read head layer regions **140**. A second insulation layer **164** is fabricated on top of the electrical leads **154** and cap layer **130**, followed by the fabrication of a second magnetic shield (not shown) and further components that are well known to those skilled in the art for fabricating a complete magnetic head.

A significant feature of the prior art lead overlaid GMR read head depicted in FIG. **1** is that the portion of the central layer region **140** which substantially defines the track reading width **W** of the read head **100** is the central portion **144** of the read head layer regions **140** that is disposed between the inner ends **156** of the electrical leads **154**. That is, because the electrical current flows through the read head layers between the electrical leads **154**, the active portion **144** of the read head layers comprises the width w between the inner ends **156** of the electrical leads **154**. The tab regions **160** of the read head layers disposed beneath the overlaid inner ends **156** of the electrical leads **154** are somewhat passive in that only a small amount of electrical current passes through them between the electrical leads **154**.

A problem that has been recognized with regard to such prior art lead overlaid read heads is that the passive region of the magnetic layers of the read head, and particularly the free magnetic layer, is not entirely passive. That is, external magnetic

fields, such as from adjacent data tracks, create magnetic field fluctuation and noise within the passive regions of the free magnetic layer beneath the electrical leads. Thus, noise and side reading effects continue to be a problem with lead overlaid GMR read heads.

Further, such prior art heads require hard bias material on either side of the sensor to exert magnetic force on the free layer to magnetically stabilize the free layer. The problem is that hard bias layers are very thick, and as track sizes shrink, sensors must get smaller. When the track width becomes very narrow, the hard bias layers make the free layer very insensitive and thus less effective. What is needed is a way to create a sensor with a narrow track width, yet with a free layer that is very sensitive.

To overcome the problems described above, designers have turned to providing in-stack bias layers in the tab regions. FIG. **2** depicts another prior art lead overlaid read head **200** having a structure similar to that of FIG. **1**. As depicted in FIG. **2**, the read head **200** includes a GMR read head thin film element **140**, but does not include the hard bias elements, which have been replaced by an insulating material. Instead, this read head **200** includes bias layers **202** that are formed above the tab regions **160**, such that an inner portion **204** of the layer **202** extends over the tab regions **160** of the layers that comprise the read head element **140**. The bias layer **202** is deposited full film on top of an antiparallel (AP) coupling layer **206**, the AP coupling layer providing antiparallel coupling between the bias layer **202** and the free layer **126**. The AP coupling layer **206** is formed of Ru having a thickness of about 8Å. The electrical leads **154** are thereafter fabricated on top of the bias layer **202**. Then the portions of the leads **154** and bias layer

202 overlying the central portion **144** of the read head **200** are removed such as by etching (e.g., ion beam etching) or milling.

Because the inner portion **204** of the bias layer **202** are present only above the tab regions **160** of the AP coupling layer **206**, which is deposited above the tab regions **160** of the free layer **126**, the magnetic field within the inner portion **204** of the bias layers **202** will become magnetostatically coupled to the tab regions **160** of the free layer **126** through the AP coupling layer **206**. This provides a pinning effect upon the magnetic fields within the tab regions **160** of the free layer **126**, making the free layer **126** active only in the active area **144** and passive in the tab regions **160**. The resulting structure is known as an AP-tab design.

A problem that has been recognized with regard to prior art lead overlaid read heads such as the head **200** shown in FIG. **2** is that during removal of the bias layer **202** from above the active region **144**, the etching or milling can mill through the thin (8Å) Ru AP coupling layer **206**, resulting in damage to the underlying free layer **126**. This damage in turn results in problems such as reading errors and instability. Also, it is desirable to avoid oxidation of the free layer **126**. Removal of portions of the Ru coupling layer **206** exposes portions of the free layer **126**, making it susceptible to corrosion.

What is therefore needed is a new structure that provides a thicker AP coupling layer that provides more protection to the underlying free layer during removal of the bias layer from the active portion of the read head.

SUMMARY OF THE INVENTION

The present invention overcomes the drawbacks and limitations described above by providing a magnetic head that uses a thick AP coupling layer in an AP-tab structure. Accordingly, the head includes a free layer having an active area and tab regions on opposite sides of the active area. An antiparallel (AP) coupling layer is formed above the free layer. In one embodiment, the AP coupling layer has a thickness of 15Å or more. In another embodiment, the AP coupling layer is formed of Ir, and preferably has a thickness of 15Å or more. A bias layer is formed above each of the tab portions of the free layer, magnetic moments of the tab regions of the free layer being pinned antiparallel to the magnetic moments of the bias layers. The bias layers can be formed of NiFe, CoFe, Ta, Ru and laminates thereof.

Preferably, the AP coupling layer has a coupling strength of at least about 0.5 erg/cm^2. In an embodiment, the head may further include an AP pinned layer structure below the free layer, the AP pinned layer structure including at least two pinned layers having magnetic moments that are self-pinned antiparallel to each other, the pinned layers being separated by another AP coupling layer. In a preferred embodiment, the pinned layers of the AP pinned layer structure are formed of CoFe.

The free layer is preferably formed on a layer of Cu or NiFe, which act as an underlayer to the AP tab structure and provide improved AP coupling and thermal stability.

Other aspects and advantages of the present invention will become apparent from the following detailed description, which, when taken in conjunction with the drawings, illustrate by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and advantages of the present invention, as well as the preferred mode of use, reference should be made to the following detailed description read in conjunction with the accompanying drawings.

FIG. **1** is a side cross-sectional view of a prior art lead overlaid read head portion of a magnetic head.

FIG. **2** is a side cross-sectional view of another prior art lead overlaid read head portion of a magnetic head.

FIG. **3** is a perspective drawing of a magnetic disk drive system in accordance with one embodiment.

FIG. **4** is a partial view of the slider and a merged magnetic head.

FIG. **5** is a partial ABS view, not to scale, of the slider taken along plane **5-5** of FIG. **4** to show the read and write elements of the merged magnetic head.

FIG. **6** is a side cross-sectional view of a first preferred embodiment of a lead overlaid read head portion of a magnetic head of the present invention.

FIG. **7** is a chart **700** depicting the coupling strength of Ir in an AP pinned structure of CoFe/Ir/CoFe.

FIG. **8** is a side cross-sectional view of a second preferred embodiment of a lead overlaid read head portion of a magnetic head of the present invention.

FIG. **9** is a side cross-sectional view of a third preferred embodiment of a lead overlaid read head portion of a magnetic head of the present invention.

FIG. **10** is a side cross-sectional view of a fourth preferred embodiment of a lead overlaid read head portion of a magnetic head of the present invention.

FIG. **11** is a side cross-sectional view of a fourth preferred embodiment of a lead overlaid read head portion of a magnetic head of the present invention.

Best Mode for Carrying Out the Invention

The following description is the best embodiment presently contemplated for carrying out the present invention. This description is made for the purpose of illustrating the general principles of the present invention and is not meant to limit the inventive concepts claimed herein.

Referring now to FIG. **3**, there is shown a disk drive **300** embodying the present invention. As shown in FIG. **3**, at least one rotatable magnetic disk **312** is supported on a spindle **314** and rotated by a disk drive motor **318**. The magnetic recording on each disk is in the form of an annular pattern of concentric data tracks (not shown) on the disk **312**.

At least one slider **313** is positioned near the disk **312**, each slider **313** supporting one or more magnetic read/write heads **321**. More information regarding such heads **321** will be set forth hereinafter during reference to FIG. **4**. As the disks rotate, slider **313** is moved radially in and out over disk surface **322** so that heads **321** may access different tracks of the disk where desired data are recorded. Each slider **313** is attached to an actuator arm **319** by means way of a suspension **315**. The suspension **315** provides a slight spring force which biases slider **313** against the disk surface **322**. Each actuator arm **319** is attached to an actuator means **327**. The actuator means **327** as shown in FIG. **3** may be a voice coil motor (VCM). The VCM comprises a coil movable within a fixed magnetic field, the direction and speed of the coil movements being controlled by the motor current signals supplied by controller **329**.

During operation of the disk storage system, the rotation of disk **312** generates an air bearing between slider **313** and disk surface **322** which exerts an upward force or lift on the slider. The air bearing thus counter-balances the slight spring force of suspension **315** and supports slider **313** off and slightly above the disk surface by a small, substantially constant spacing during normal operation.

The various components of the disk storage system are controlled in operation by control signals generated by control unit **329**, such as access control signals and internal clock signals. Typically, control unit **329** comprises logic control circuits, storage means and a microprocessor. The control unit **329** generates control signals to control various system operations such as drive motor control signals on line **323** and head position and seek control signals on line **328**. The control signals on line **328** provide the desired current profiles to optimally move and position slider **313** to the desired data track on disk **312**. Read and write signals are communicated to and from read/write heads **321** by way of recording channel **325**.

The above description of a typical magnetic disk storage system, and the accompanying illustration of FIG. **3** are for representation purposes only. It should be apparent that disk storage systems may contain a large number of disks and actuators, and each actuator may support a number of sliders.

FIG. **4** is a side cross-sectional elevation view of a merged magnetic head **400**, which includes a write head portion **402** and a read head portion **404**, the read head portion employing a spin valve sensor **406** of the present invention. FIG. **5** is an ABS view of FIG. **4**. The spin valve sensor **406** is sandwiched between nonmagnetic electrically insulative first and second read gap layers **408** and **410**, and the read gap

layers are sandwiched between ferromagnetic first and second shield layers **412** and **414**. In response to external magnetic fields, the resistance of the spin valve sensor **406** changes. A sense current (I_s) conducted through the sensor causes these resistance changes to be manifested as potential changes. These potential changes are then processed as readback signals by the processing circuitry **329** shown in FIG. **3**.

The write head portion **402** of the magnetic head **400** includes a coil layer **422** sandwiched between first and second insulation layers **416** and **418**. A third insulation layer **420** may be employed for planarizing the head to eliminate ripples in the second insulation layer caused by the coil layer **422**. The first, second and third insulation layers are referred to in the art as an "insulation stack". The coil layer **422** and the first, second and third insulation layers **416**, **418** and **420** are sandwiched between first and second pole piece layers **424** and **426**. The first and second pole piece layers **424** and **426** are magnetically coupled at a back gap **428** and have first and second pole tips **430** and **432** which are separated by a write gap layer **434** at the ABS. Since the second shield layer **414** and the first pole piece layer **424** are a common layer this head is known as a merged head. In a piggyback head an insulation layer is located between a second shield layer and a first pole piece layer. First and second solder connections (not shown) connect leads (not shown) from the spin valve sensor **406** to leads (not shown) on the slider **313** (FIG. **3**), and third and fourth solder connections (not shown) connect leads (not shown) from the coil **422** to leads (not shown) on the suspension.

FIG. **6** illustrates a lead overlaid read head **600** according to one preferred embodiment. As shown, the read head **600** includes a substrate base **602**, a first magnetic shield (S1) **604** fabricated on the substrate, and an insulation layer (IL1) **606** fabricated

upon the magnetic shield **604**. Seed layers (SL) **608** are deposited upon the insulation layer **606** and a series of thin film layers are sequentially deposited upon the seed layers **608** to form a read head. The seed layers aid in creating the proper growth structure of the layers above them. Note that the materials used to form the seed layers can be varied, and will depend on the desired processing parameters.

Then an antiparallel (AP) pinned layer structure **612** is formed above the seed layers **608**. As shown in FIG. **6**, first and second AP pinned magnetic layers, (AP1) and (AP2) **624, 626**, are separated by a thin layer (APC1) **628** of an antiparallel coupling material such that the magnetic moments of the AP pinned layers **624, 626** are self-pinned antiparallel to each other. The pinned layers **624, 626** have a property known as magnetostriction. The magnetostriction of the pinned layers **624, 626** is very positive. The head **600** is also under compressive stresses because of its geometry at the ABS, and the configuration of the layer is such that it produces very large compressive stress. The combination of positive magnetostriction and compressive stress causes the pinned layers **624, 626** to develop a magnetic anisotropy that is in a perpendicular direction to the track width. This magnetic coupling through the Ru spacer causes the pinned layers **624, 626** to have antiparallel-oriented magnetizations.

In the embodiment shown in FIG. **6**, the preferred magnetic orientation of the pinned layers **624**, **626** is for the first pinned layer **624**, out of the face of the structure depicted (perpendicular to the ABS of the head **600**), and into the face for the second pinned layer **626**. Illustrative materials for the pinned layers **624, 626** are $CoFe_{10}$ (90% Co, 10% Fe), $CoFe_{50}$ (50% Co, 50% Fe), etc. separated by an antiparallel coupling layer **628** of Ru. Illustrative thicknesses of the first and second pinned layers **624, 626** are

between about 10Å and 25Å. The Ru layer **628** can be about 5-15Å, but is preferably selected to provide a saturation field above about 10 KOe. In a preferred embodiment, each of the pinned layers **624, 626** is about 18Å with a Ru layer **628** therebetween of about 8Å.

The AP pinned layer structure **612** can be stabilized by placement of an antiferromagnetic (AFM) layer **610** below the pinned layer structure **612**. The AFM layer **610** pins the AP pinned layer structure **612** so that the pinned layers **624, 626** do not move around when disk is reading data from disk, upon application of external magnetic fields, etc. Note that the head may or may not include an AFM layer **610**.

A spacer layer (SP) **640** is added above the AP pinned layer structure **612**. The preferred material for forming the spacer layer **640** is Cu. The inventors have found that Cu improves the interfacial exchange of AP pinned layer structures containing Ir.

A free magnetic layer (FL) **644** is formed above the spacer layer **640**. The free layer **644** may be composed of CoFe, NiFe, FeN, Co, etc. and laminates of such materials. A second AP coupling layer (APC2) **650** is formed above the free layer **644**. A bias layer **660** is formed full film above the second AP coupling layer **650**. The bias layer **660** may be formed of CoFe, NiFe, FeN, Co, etc. and laminates of these materials.

Whatever combination of materials is used, the magnetic moments of the free and bias layers **644, 660** should be antiparallel. This is achieved by using Iridium (Ir) for the second AP coupling layer **650**, preferably at a thickness of about 15-30Å, ideally about 20Å if CoFe10 free and bias layers are used, and providing a coupling strength of greater than about 0.5 erg/cm^2. The benefits of using Ir as the second AP coupling layer **650** will be set forth in more detail below.

Then leads **670** are formed above the bias layer **660** in the tab regions **664** by any suitable process. Processes that can be used to form the leads **670** include additive and subtractive processes. One additive process includes a patterning process in which a lithography mask (not shown) is added to the wafer stack and conductive material is added to form the leads **670**. Then the lithography mask is removed from the wafer stack, leaving a gap between the leads **670**. According to a subtractive process, lead material is added to the wafer stack and material is removed from the lead material to define a gap above the active area **662** with leads **670** on opposite sides thereof. A preferred method for removing the lead material from the gap area is Reactive Ion Etching (RIE).

The portion of the bias layer **660** in the active area **662** is removed to eliminate its magnetic properties in the active area **662**, thereby allowing the free layer **644** in the active area **662** to spin freely. This allows the head to read track widths in the sub-micron range. Further, each tab region (overlap area) **664** can be much longer than the active area **662** because the antiparallel coupling makes the overlap portions **664** insensitive.

A cap layer (CAP) **680** is deposited above the second AP coupling layer **650** in the active area **662**. A preferred material for the cap layer **680** is Ta. A second insulation layer (IL2) **690** is fabricated on top of the electrical leads **670** and cap layer **680**, followed by the fabrication of a second magnetic shield (not shown) and further components, such as a write portion, that are well known to those skilled in the art for fabricating a complete magnetic head.

The portion of the bias layer **660** in the active area **662** is removed down to the second AP coupling layer **650** by any suitable process. One process is ion beam etching or RIE. Another process is oxidation of the bias layer to make it magnetically dead.

However, as mentioned above, a risk of etching or milling through the second AP coupling layer **650** and damaging the underlying free layer **644** exists. Any damage to the free layer **644** can result in an inoperable head, or a head that does not function as desired. Also, it is desirable to avoid oxidation of the free layer **644**. Removal of portions of the second AP coupling layer **650** exposes portions of the free layer **644**, making it susceptible to corrosion.

Iridium provides antiferromagnetic exchange coupling to $CoFe_{10}$ comparable to Ru, but at a much greater thickness, thereby providing more protection to the free layer **644**. FIG. **7** is a chart **700** depicting the coupling strength of Ir in an AP pinned structure of $CoFe_{10}$/Ir/$CoFe_{10}$ grown onto a Ta/Cu underlayer. As shown, exchange coupling through Ir is best at about 20Å Ir, where the Ir has a coupling coefficient (J) of between about 0.5 and 1 erg/cm^2 To get comparable coupling strength with Ru, e.g., J = 0.8 erg/cm^2, the layer of Ru must be very thin, on the order of about 5-8Å. At greater Ru thickness, the coupling decreases. For example, a Ru layer of 20Å thickness provides very little antiparallel coupling.

Thus, the benefit of using Ir as the second AP coupling layer **650** is that the thicker Ir layer provides more protection to free layer **644** during processing. The larger margin of error results in higher yields and makes this type of design feasible. The phase of the oscillations in coupling strength will change with CoFe composition. Accordingly the Ir thickness at which strong antiferromagnetic coupling is obtained will change with CoFe composition. $CoFe_{10}$ is used for illustrating the general principles of the present invention and is not meant to limit the inventive concepts claimed herein. Other CoFe

compositions may be used with an Ir thickness adjusted to a thickness where strong antiferromagnetic coupling is obtained. The preferred Ir thickness is 15 Å or more.

FIG. **8** illustrates a lead overlaid read head **800** according to another embodiment. This head **800** is similar to the head **600** shown in FIG. **6**, except that the bias layer **660** is formed of CoFe. In this embodiment, the Cu spacer layer **640** acts as an underlayer for formation of a CoFe/Ir/CoFe AP-tab structure. Underlayers are known to have an influence on crystalline growth direction and growth mode. CoFe is face centered cubic (fcc) as opposed to hexagonically closed packed (hcp) for Co, or body centered cubic (bcc) for Fe. The Cu underlayer as well as the Ir coupling layer are fcc. The inventors have found that the use of a Cu underlayer for formation of a CoFe/Ir/CoFe AP tab structure **612** results in increased interfacial exchange.

$NiFe_{80}$ is another good underlayer that shows improved thermal stability over Cu. Since $NiFe_{80}$ is magnetic it can be inserted in between the Cu spacer and the CoFe layer and act as part as an underlayer for CoFe as well as a part of the free layer. $NiFe_{80}$ is also fcc. Other fcc NiFe compositions may also be used.

FIG. **9** illustrates a head **900** that is similar to the head **800** shown in FIG. **8**, except that a NiFe layer is inserted in between the Cu spacer **640** and the CoFe free layer **644**. In this embodiment, the NiFe layer **642** acts as an underlayer (UL) for formation of a CoFe/Ir/CoFe AP-tab structure.

FIG. **10** illustrates a head **1000** that is similar to the head **900** shown in FIG. **9**, except that a CoFe/NiFe layer **642** is inserted in between the Cu spacer **640** and the CoFe free layer. In this embodiment, the NiFe layer **642** acts as an underlayer for formation of a CoFe/Ir/CoFe AP-tab structure.

FIG. **11** illustrates a lead overlaid read head **1100** according to yet another embodiment. This head **1100** is similar to the head **600** shown in FIG. **6**, except that the bias layer **660** is formed of CoFe/NiFe/Ta/Ru.

While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. For example, the structures and methodologies presented herein are generic in their application to all MR heads, AMR heads, GMR heads, spin valve heads, etc. Thus, the breadth and scope of a preferred embodiment should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.